

Preliminary Classification:

Proposed Class:

Subclass:

NOTE: "All applicants are requested to include a preliminary classification on newly filed patent applications. The preliminary classification, preferably class and subclass designations, should be identified in the upper right-hand corner of the letter of transmittal accompanying the application papers, for example 'Proposed Class 2, subclass 129.'" M.P.E.P. § 601, 7th ed.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Box Patent Application
Assistant Commissioner for Patents
Washington, D.C. 20231

NEW APPLICATION TRANSMITTAL

Transmitted herewith for filing is the patent application of

Inventor(s): Marko PARIKKA, Markku KUITTINEN, Jari TURUNEN

WARNING: 37 C.F.R. § 1.41(a)(1) points out:

"(a) A patent is applied for in the name or names of the actual inventor or inventors.

"(1) The inventorship of a nonprovisional application is that inventorship set forth in the oath or declaration as prescribed by § 1.63, except as provided for in § 1.53(d)(4) and § 1.63(d). If an oath or declaration as prescribed by § 1.63 is not filed during the pendency of a nonprovisional application, the inventorship is that inventorship set forth in the application papers filed pursuant to § 1.53(b), unless a petition under this paragraph accompanied by the fee set forth in § 1.17(i) is filed supplying or changing the name or names of the inventor or inventors."

For (title): A BACKLIGHTING LIGHT PIPE FOR ILLUMINATING A FLAT-PANEL DISPLAY

CERTIFICATION UNDER 37 C.F.R. § 1.10*
(Express Mail label number is mandatory.)
(Express Mail certification is optional.)

I hereby certify that this New Application Transmittal and the documents referred to as attached therein are being deposited with the United States Postal Service on this date December 29, 1999, in an envelope as "Express Mail Post Office to Addressee," mailing Label Number EL067144409US, addressed to the: Assistant Commissioner for Patents, Washington, D.C. 20231.

Maureen Egan
(type or print name of person mailing paper)

[Signature]
Signature of person mailing paper

WARNING: Certificate of mailing (first class) or facsimile transmission procedures of 37 C.F.R. § 1.8 cannot be used to obtain a date of mailing or transmission for this correspondence.

***WARNING:** Each paper or fee filed by "Express Mail" must have the number of the "Express Mail" mailing label placed thereon prior to mailing. 37 C.F.R. § 1.10(b).
"Since the filing of correspondence under § 1.10 without the Express Mail mailing label thereon is an oversight that can be avoided by the exercise of reasonable care, requests for waiver of this requirement will **not** be granted on petition." Notice of Oct. 24, 1996, 60 Fed. Reg. 56,439, at 56,442.

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1. Type of Application

This new application is for a(n)

(check one applicable item below)

- ☒ Original (nonprovisional)
☐ Design
☐ Plant

WARNING: Do not use this transmittal for a completion in the U.S. of an International Application under 35 U.S.C. § 371(c)(4), unless the International Application is being filed as a divisional, continuation or continuation-in-part application.

WARNING: Do not use this transmittal for the filing of a provisional application.

NOTE: If one of the following 3 items apply, then complete and attach ADDED PAGES FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF A PRIOR U.S. APPLICATION CLAIMED and a NOTIFICATION IN PARENT APPLICATION OF THE FILING OF THIS CONTINUATION APPLICATION.

- ☐ Divisional.
☐ Continuation.
☐ Continuation-in-part (C-I-P).

2. Benefit of Prior U.S. Application(s) (35 U.S.C. §§ 119(e), 120, or 121)

NOTE: A nonprovisional application may claim an invention disclosed in one or more prior filed copending nonprovisional applications or copending international applications designating the United States of America. In order for a nonprovisional application to claim the benefit of a prior filed copending nonprovisional application or copending international application designating the United States of America, each prior application must name as an inventor at least one inventor named in the later filed nonprovisional application and disclose the named inventor's invention claimed in at least one claim of the later filed nonprovisional application in the manner provided by the first paragraph of 35 U.S.C. § 112. Each prior application must also be:

- (i) An international application entitled to a filing date in accordance with PCT Article 11 and designating the United States of America; or
- (ii) Complete as set forth in § 1.51(b); or
- (iii) Entitled to a filing date as set forth in § 1.53(b) or § 1.53(d) and include the basic filing fee set forth in § 1.16; or
- (iv) Entitled to a filing date as set forth in § 1.53(b) and have paid therein the processing and retention fee set forth in § 1.21(f) within the time period set forth in § 1.53(f).

37 C.F.R. § 1.78(a)(1).

NOTE: If the new application being transmitted is a divisional, continuation or a continuation-in-part of a parent case, or where the parent case is an International Application which designated the U.S., or benefit of a prior provisional application is claimed, then check the following item and complete and attach ADDED PAGES FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION(S) CLAIMED.

WARNING: If an application claims the benefit of the filing date of an earlier filed application under 35 U.S.C. §§ 120, 121 or 365(c), the 20-year term of that application will be based upon the filing date of the earliest U.S. application that the application makes reference to under 35 U.S.C. §§ 120, 121 or 365(c). (35 U.S.C. § 154(a)(2) does not take into account, for the determination of the patent term, any application on which priority is claimed under 35 U.S.C. §§ 119, 365(a) or 365(b).) For a c-i-p application, applicant should review whether any claim in the patent that will issue is supported by an earlier application and, if not, the applicant should consider canceling the reference to the earlier filed application. The term of a patent is not based on a claim-by-claim approach. See Notice of April 14, 1995, 60 Fed. Reg. 20,195, at 20,205.

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WARNING: When the last day of pendency of a provisional application falls on a Saturday, Sunday, or Federal holiday within the District of Columbia, any nonprovisional application claiming benefit of the provisional application must be filed prior to the Saturday, Sunday, or Federal holiday within the District of Columbia. See 37 C.F.R. § 1.78(a)(3).

- ☐ The new application being transmitted claims the benefit of prior U.S. application(s). Enclosed are ADDED PAGES FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION(S) CLAIMED.

3. Papers Enclosed

A. Required for filing date under 37 C.F.R. § 1.53(b) (Regular) or 37 C.F.R. § 1.153 (Design) Application

13 Pages of specification

4 Pages of claims

12 Sheets of drawing

WARNING: DO NOT submit original drawings. A high quality copy of the drawings should be supplied when filing a patent application. The drawings that are submitted to the Office must be on strong, white, smooth, and non-shiny paper and meet the standards according to § 1.84. If corrections to the drawings are necessary, they should be made to the original drawing and a high-quality copy of the corrected original drawing then submitted to the Office. Only one copy is required or desired. For comments on proposed then-new 37 C.F.R. § 1.84, see Notice of March 9, 1988 (1990 O.G. 57-62).

NOTE: "Identifying indicia, if provided, should include the application number or the title of the invention, inventor's name, docket number (if any), and the name and telephone number of a person to call if the Office is unable to match the drawings to the proper application. This information should be placed on the back of each sheet of drawing a minimum distance of 1.5 cm. (5/8 inch) down from the top of the page . . ." 37 C.F.R. § 1.84(c)).

(complete the following, if applicable)

- ☐ The enclosed drawing(s) are photograph(s), and there is also attached a "PETITION TO ACCEPT PHOTOGRAPH(S) AS DRAWING(S)." 37 C.F.R. § 1.84(b).
- ☐ formal
- ☐ informal

B. Other Papers Enclosed

 Pages of declaration and power of attorney

1 Pages of abstract

 Other

4. Additional papers enclosed

- ☐ Amendment to claims
- ☐ Cancel in this applications claims _____ before calculating the filing fee. (At least one original independent claim must be retained for filing purposes.)
- ☐ Add the claims shown on the attached amendment. (Claims added have been numbered consecutively following the highest numbered original claims.)
- ☐ Preliminary Amendment
- ☐ Information Disclosure Statement (37 C.F.R. § 1.98)
- ☐ Form PTO-1449 (PTO/SB/08A and 08B)
- ☐ Citations

- ☐ Declaration of Biological Deposit
- ☐ Submission of "Sequence Listing," computer readable copy and/or amendment pertaining thereto for biotechnology invention containing nucleotide and/or amino acid sequence.
- ☐ Authorization of Attorney(s) to Accept and Follow Instructions from Representative
- ☐ Special Comments
- ☐ Other

5. Declaration or oath (including power of attorney)

NOTE: A newly executed declaration is not required in a continuation or divisional application provided that the prior nonprovisional application contained a declaration as required, the application being filed is by all or fewer than all the inventors named in the prior application, there is no new matter in the application being filed, and a copy of the executed declaration filed in the prior application (showing the signature or an indication thereon that it was signed) is submitted. The copy must be accompanied by a statement requesting deletion of the names of person(s) who are not inventors of the application being filed. If the declaration in the prior application was filed under § 1.47, then a copy of that declaration must be filed accompanied by a copy of the decision granting § 1.47 status or, if a nonsigning person under § 1.47 has subsequently joined in a prior application, then a copy of the subsequently executed declaration must be filed. See 37 C.F.R. §§ 1.63(d)(1)-(3).

NOTE: A declaration filed to complete an application must be executed, identify the specification to which it is directed, identify each inventor by full name including family name and at least one given name, without abbreviation together with any other given name or initial, and the residence, post office address and country or citizenship of each inventor, and state whether the inventor is a sole or joint inventor. 37 C.F.R. § 1.63(a)(1)-(4).

- ☐ Enclosed
- Executed by

(check all applicable boxes)

- ☐ inventor(s).
- ☐ legal representative of inventor(s).
37 C.F.R. §§ 1.42 or 1.43.
- ☐ joint inventor or person showing a proprietary interest on behalf of inventor who refused to sign or cannot be reached.
 - ☐ This is the petition required by 37 C.F.R. § 1.47 and the statement required by 37 C.F.R. § 1.47 is also attached. See item 13 below for fee.

- ☒ Not Enclosed.

NOTE: Where the filing is a completion in the U.S. of an International Application or where the completion of the U.S. application contains subject matter in addition to the International Application, the application may be treated as a continuation or continuation-in-part, as the case may be, utilizing ADDED PAGE FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION CLAIMED.

- ☒ Application is made by a person authorized under 37 C.F.R. § 1.41(c) on behalf of all the above named inventor(s).

(The declaration or oath, along with the surcharge required by 37 C.F.R. § 1.16(e) can be filed subsequently).

- ☐ Showing that the filing is authorized.
(not required unless called into question. 37 C.F.R. § 1.41(d))

6. Inventorship Statement

WARNING: If the named inventors are each not the inventors of all the claims an explanation, including the ownership of the various claims at the time the last claimed invention was made, should be submitted.

The inventorship for all the claims in this application are:

☐ The same.

or

☐ Not the same. An explanation, including the ownership of the various claims at the time the last claimed invention was made,

☐ is submitted.

☐ will be submitted.

7. Language

NOTE: An application including a signed oath or declaration may be filed in a language other than English. An English translation of the non-English language application and the processing fee of \$130.00 required by 37 C.F.R. § 1.17(k) is required to be filed with the application, or within such time as may be set by the Office. 37 C.F.R. § 1.52(d).

☒ English

☐ Non-English

☐ The attached translation includes a statement that the translation is accurate. 37 C.F.R. § 1.52(d).

8. Assignment

☒ An assignment of the invention to Nokia Mobile Phones Ltd.

☐ is attached. A separate ☐ "COVER SHEET FOR ASSIGNMENT (DOCUMENT) ACCOMPANYING NEW PATENT APPLICATION" or ☐ FORM PTO 1595 is also attached.

☒ will follow.

NOTE: "If an assignment is submitted with a new application, send two separate letters—one for the application and one for the assignment." Notice of May 4, 1990 (1114 O.G. 77-78).

WARNING: A newly executed "CERTIFICATE UNDER 37 C.F.R. § 3.73(b)" must be filed when a continuation-in-part application is filed by an assignee. Notice of April 30, 1993, 1150 O.G. 62-64.

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9. Certified Copy

Certified copy(ies) of application(s)

Country	Appln. No.	Filed
Finland	982825	30 December 1998
Country	Appln. No.	Filed
Country	Appln. No.	Filed

from which priority is claimed

☒ Is (are) attached.☐ will follow.

NOTE: The foreign application forming the basis for the claim for priority must be referred to in the oath or declaration. 37 C.F.R. § 1.55(a) and 1.63.

NOTE: This item is for any foreign priority for which the application being filed directly relates. If any parent U.S. application or International Application from which this application claims benefit under 35 U.S.C. § 120 is itself entitled to priority from a prior foreign application, then complete Item 18 on the ADDED PAGES FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION(S) CLAIMED.

10. Fee Calculation (37 C.F.R. § 1.16)A. ☒ Regular application

CLAIMS AS FILED					
Number filed		Number Extra	Rate		Basic Fee 37 C.F.R. § 1.16(a) \$ 690.00
Total					
Claims (37 C.F.R. § 1.16(c))	18 - 20 =	0	×	\$ 18.00	0
Independent Claims (37 C.F.R. § 1.16(b))	2 - 3 =	0	×	\$ 78.00	0
Multiple dependent claim(s), if any (37 C.F.R. § 1.16(d))					+ \$260.00

☐ Amendment cancelling extra claims is enclosed.☐ Amendment deleting multiple-dependencies is enclosed.☐ Fee for extra claims is not being paid at this time.

NOTE: If the fees for extra claims are not paid on filing they must be paid or the claims cancelled by amendment, prior to the expiration of the time period set for response by the Patent and Trademark Office in any notice of fee deficiency. 37 C.F.R. § 1.16(d).

Filing Fee Calculation

\$ 690.00

B. ☐ Design application

(\$310.00—37 C.F.R. § 1.16(f))

Filing Fee Calculation

\$

C. ☐ Plant application

(\$480.00—37 C.F.R. § 1.16(g))

Filing fee calculation

\$

11. Small Entity Statement(s)

- ☐ Statement(s) that this is a filing by a small entity under 37 C.F.R. § 1.9 and 1.27 is (are) attached.

WARNING: "Status as a small entity must be specifically established in each application or patent in which the status is available and desired. Status as a small entity in one application or patent does not affect any other application or patent, including applications or patents which are directly or indirectly dependent upon the application or patent in which the status has been established. The refiling of an application under § 1.53 as a continuation, division, or continuation-in-part (including a continued prosecution application under § 1.53(d)), or the filing of a reissue application requires a new determination as to continued entitlement to small entity status for the continuing or reissue application. A nonprovisional application claiming benefit under 35 U.S.C. § 119(e), 120, 121, or 365(c) of a prior application, or a reissue application may rely on a statement filed in the prior application or in the patent if the nonprovisional application or the reissue application includes a reference to the statement in the prior application or in the patent or includes a copy of the statement in the prior application or in the patent and status as a small entity is still proper and desired. The payment of the small entity basic statutory filing fee will be treated as such a reference for purposes of this section." 37 C.F.R. § 1.28(a)(2).

WARNING: "Small entity status must not be established when the person or persons signing the . . . statement can unequivocally make the required self-certification." M.P.E.P., § 509.03, 6th ed., rev. 2, July 1996 (emphasis added).

(complete the following, if applicable)

- ☐ Status as a small entity was claimed in prior application
_____ / _____, filed on _____, from which benefit
is being claimed for this application under:
35 U.S.C. § ☐ 119(e),
☐ 120,
☐ 121,
☐ 365(c),

and which status as a small entity is still proper and desired.

- ☐ A copy of the statement in the prior application is included.

Filing Fee Calculation (50% of A, B or C above)

\$ _____

NOTE: Any excess of the full fee paid will be refunded if small entity status is established and a refund request are filed within 2 months of the date of timely payment of a full fee. The two-month period is not extendable under § 1.136. 37 C.F.R. § 1.28(a).

12. Request for International-Type Search (37 C.F.R. § 1.104(d))

(complete, if applicable)

- ☐ Please prepare an international-type search report for this application at the time when national examination on the merits takes place.

13. Fee Payment Being Made at This Time

☐ Not Enclosed

☐ No filing fee is to be paid at this time.

(This and the surcharge required by 37 C.F.R. § 1.16(e) can be paid subsequently.)

☒ Enclosed

☒ Filing fee \$ 690.00

☐ Recording assignment
(\$40.00; 37 C.F.R. § 1.21(h))
(See attached "COVER SHEET FOR
ASSIGNMENT ACCOMPANYING NEW
APPLICATION".) \$ _____

☐ Petition fee for filing by other than all the
inventors or person on behalf of the inventor
where inventor refused to sign or cannot be
reached
(\$130.00; 37 C.F.R. §§ 1.47 and 1.17(i)) \$ _____

☐ For processing an application with a
specification in
a non-English language
(\$130.00; 37 C.F.R. §§ 1.52(d) and 1.17(k)) \$ _____

☐ Processing and retention fee
(\$130.00; 37 C.F.R. §§ 1.53(d) and 1.21(l)) \$ _____

☐ Fee for international-type search report
(\$40.00; 37 C.F.R. § 1.21(e)) \$ _____

NOTE: 37 C.F.R. § 1.21(f) establishes a fee for processing and retaining any application that is abandoned for failing to complete the application pursuant to 37 C.F.R. § 1.53(f) and this, as well as the changes to 37 C.F.R. §§ 1.53 and 1.78(a)(1), indicate that in order to obtain the benefit of a prior U.S. application, either the basic filing fee must be paid, or the processing and retention fee of § 1.21(l) must be paid, within 1 year from notification under § 53(f).

Total fees enclosed \$ 690.00

14. Method of Payment of Fees

☒ Check in the amount of \$ 690.00

☐ Charge Account No. _____ in the amount of
\$ _____

A duplicate of this transmittal is attached.

NOTE: Fees should be itemized in such a manner that it is clear for which purpose the fees are paid. 37 C.F.R. § 1.22(b).

15. Authorization to Charge Additional Fees

WARNING: If no fees are to be paid on filing, the following items should not be completed.

WARNING: Accurately count claims, especially multiple dependent claims, to avoid unexpected high charges, if extra claim charges are authorized.

- ☒ The Commissioner is hereby authorized to charge the following additional fees by this paper and during the entire pendency of this application to Account No. 16-1350:

☒ 37 C.F.R. § 1.16(a), (f) or (g) (filing fees)

☒ 37 C.F.R. § 1.16(b), (c) and (d) (presentation of extra claims)

NOTE: Because additional fees for excess or multiple dependent claims not paid on filing or on later presentation must only be paid or these claims cancelled by amendment prior to the expiration of the time period set for response by the PTO in any notice of fee deficiency (37 C.F.R. § 1.16(d)), it might be best not to authorize the PTO to charge additional claim fees, except possibly when dealing with amendments after final action.

☒ 37 C.F.R. § 1.16(e) (surcharge for filing the basic filing fee and/or declaration on a date later than the filing date of the application)

☒ 37 C.F.R. § 1.17(a)(1)-(5) (extension fees pursuant to § 1.136(a)).

☐ 37 C.F.R. § 1.17 (application processing fees)

NOTE: ". . . A written request may be submitted in an application that is an authorization to treat any concurrent or future reply, requiring a petition for an extension of time under this paragraph for its timely submission, as incorporating a petition for extension of time for the appropriate length of time. An authorization to charge all required fees, fees under § 1.17, or all required extension of time fees will be treated as a constructive petition for an extension of time in any concurrent or future reply requiring a petition for an extension of time under this paragraph for its timely submission. Submission of the fee set forth in § 1.17(a) will also be treated as a constructive petition for an extension of time in any concurrent reply requiring a petition for an extension of time under this paragraph for its timely submission." 37 C.F.R. § 1.136(a)(3).

☐ 37 C.F.R. § 1.18 (issue fee at or before mailing of Notice of Allowance, pursuant to 37 C.F.R. § 1.311(b))

NOTE: Where an authorization to charge the issue fee to a deposit account has been filed before the mailing of a Notice of Allowance, the issue fee will be automatically charged to the deposit account at the time of mailing the notice of allowance. 37 C.F.R. § 1.311(b).

NOTE: 37 C.F.R. § 1.28(b) requires "Notification of any change in status resulting in loss of entitlement to small entity status must be filed in the application . . . prior to paying, or at the time of paying, . . . the issue fee. . . ." From the wording of 37 C.F.R. § 1.28(b), (a) notification of change of status must be made even if the fee is paid as "other than a small entity" and (b) no notification is required if the change is to another small entity.

16. Instructions as to Overpayment

NOTE: ". . . Amounts of twenty-five dollars or less will not be returned unless specifically requested within a reasonable time, nor will the payer be notified of such amounts; amounts over twenty-five dollars may be returned by check or, if requested, by credit to a deposit account." 37 C.F.R. § 1.26(a).

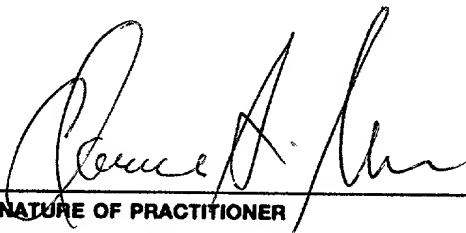
- ☒ Credit Account No. 16-1350
☐ Refund

SEND ALL CORRESPONDENCE TO:

Reg. No. 24,622

Tel. No. (203) 259-1800

Customer No.



SIGNATURE OF PRACTITIONER
Clarence A. Green

(type or print name of attorney)
PERMAN & GREEN, LLP

P.O. Address
425 Post Road, Fairfield, Connecticut 06430

☐ **Incorporation by reference of added pages**

(check the following item if the application in this transmittal claims the benefit of prior U.S. application(s) (including an international application entering the U.S. stage as a continuation, divisional or C-I-P application) and complete and attach the ADDED PAGES FOR NEW APPLICATION TRANSMITTAL WHERE BENEFIT OF PRIOR U.S. APPLICATION(S) CLAIMED)

- ☐ Plus Added Pages for New Application Transmittal Where Benefit of Prior U.S. Application(s) Claimed

Number of pages added _____

- ☐ Plus Added Pages for Papers Referred to in Item 4 Above

Number of pages added _____

- ☐ Plus added pages deleting names of inventor(s) named in prior application(s) who is/are no longer inventor(s) of the subject matter claimed in this application.

Number of pages added _____

- ☐ Plus "Assignment Cover Letter Accompanying New Application"

Number of pages added _____

☒ **Statement Where No Further Pages Added**

(if no further pages form a part of this Transmittal, then end this Transmittal with this page and check the following item)

- ☒ This transmittal ends with this page.

TITLE: A backlighting light pipe for illuminating a flat-panel display

TECHNOLOGICAL FIELD

The invention relates to uniform backlighting of flat-panel displays by means of a thin light pipe.

5 BACKGROUND OF THE INVENTION

Modern electronic devices often have a liquid crystal display to transmit information to the user. In order to make the display readable even in twilight or darkness, the display is generally lit by means of light emitting diodes (LED), but especially in portable devices powered by a battery and/or an accumulator, this also has a shortening effect on the actual operating time of the device. In addition, the requirement for uniform brightness of the display is essential in view of readability, but it increases power consumption to compensate for the loss of light caused by diffuser plates and the like. Instead of using opaque baffles, an alternative is to use a diffractive light pipe structure to conduct the light in the favorable direction, from the light source to the display, whereby there is also more freedom for the disposition of components.

With regard to known techniques related to the art of the invention, reference is made to solutions described in connection with the prior art (figures 1 to 2). A known arrangement is to use 'thick', 'plate-like' light pipes, on one end of which there is a light source, and on one flat side of the plate with the largest area and/or inside the light pipe there is a lighted object for achieving uniform illumination thereof. It is also known that when the light pipe is made thinner, the distribution of the illumination of the display may become less advantageous. However, there is very little extra room in modern mobile stations and other equipment provided with a display, and thick light pipe structures cannot be used in them without a negative effect on the usability of the device. Thick elements also mean increased material costs to the manufacturer and thereby more pressure on pricing.

There are also known techniques with a thin, plate-like light pipe, from one end of which a light source emits light to the space between the upper and lower surfaces of the light pipe. The bottom of the light pipe may be randomly roughened, e.g. the lower surface of a plate-like light pipe, when the display or a corresponding object to be illuminated is positioned above the upper surface of the light pipe, in the direction of the viewer. The purpose of the roughening is to distribute the light to scatter as uniformly as possible in the direction of the display. There may also be a

diffuser, a reflector or a corresponding extra layer under the roughened surface to direct the light that has passed through the roughening back to the light pipe, through it and from it in the direction of the display to increase its illumination.

Although it is the total reflection principle that the propagating light obeys on its way through the light pipe, the random roughening on the light pipe surface may cause problems to the homogeneity of the light, especially at the opposite end to the light source. In other words, much less light comes to the other end of the display than left the first end of the light pipe at the light source. Increasing the number of light sources as well as increasing their power, combined with the use of diffuser plates between the light pipe and the display and/or the light source and the light pipe improve the uniformity of illumination, but also increase power consumption and space requirements.

Figure 1A illustrates the lighting arrangement of display 1 by using a thin, flat light pipe 3, the lower surface 4 of which is randomly roughened. Figure 1B represents the local efficiency of the light source, by which light produced by the light source can be converted to backlighting (outcoupling efficiency η hereinafter). The local outcoupling efficiency is represented as a function of location, the coordinate measured from the source end of the light pipe. Because the outcoupling efficiency itself is constant all the way, the brightness of the display as seen by an outside observer is according to Figure 1C, which thus represents the local brightness of a slice of the display as a function of the distance measured from the end at the light source. Figure 1D shows in principle how individual rays 5 and 6 leaving a light source L1 propagate in a light pipe 3 and are converted into background light at points 5A to 5E, 6A and 6B.

Another technique for evening out the inhomogeneous brightness, which changes as a function of location as shown in Figure 1C, is to change the local outcoupling efficiency η as a function of distance by placing dots at which the light is scattered or reflected on the top or bottom of the light pipe. The dots are, for instance, small lenses, which are located at long intermediate distances in the first end of the light source and at shorter intermediate distances in the other end so that there is a smaller difference in brightness B between the first and second end of the display. Figure 2 illustrates a known arrangement like that described above for illuminating a flat-panel display 7 with a light pipe 9, in which arrangement the lower surface of the light pipe 9 is covered with lenses. The amount of light 8 is greater in the first end of the light pipe 9 near the light source L2 than in the second, opposite end. Because the purpose is to illuminate the display more uniformly, and the local outcoupling

efficiency η of the light depends on the local number of scattering and/or reflecting lenses, it is advantageous to make the density of the optical elements smaller near the light source than far from it. To improve the lighting still more, a reflector 10 can be used to return unfavorably directed light back to the direction of the display

5 7.

Estimating the transmission properties of the light pipe either by experimental or calculatory methods by using known techniques is practically impossible because of the great number of prototypes needed and the number and small size of the lenses, whereby obtaining an acceptable, optimal result with the known technique is

10 questionable.

SUMMARY OF THE INVENTION

It is an objective of the invention to provide a new light pipe, which provides uniform illumination of the background of the display and which is easy to manufacture.

15 For producing the backlighting of a flat-panel display, a patterned light pipe is used in the invention, in which light pipe at least one surface has been treated to achieve diffraction properties, by which the local outcoupling efficiency of the light pipe can be changed as a function of the distance and/or wavelength measured from the light source. The outcoupling efficiency of the light pipe depends on at least one

20 parameter, which describes the diffraction properties of the surface. The local outcoupling efficiency is influenced by quantities characterizing the diffractive surface, such as the periodicity of the surface formations of the patterns of the diffraction profile, the period d , the fill factor c and/or the height/depth of the ridges/grooves of the profile. Surface formations that are suitable as basic

25 diffraction profiles according to a preferred embodiment of the invention include binary, rectangular wave, sinusoidal, and/or triangular wave, and by forming suitable combinations thereof the properties of the invention can be optimized for each application.

In addition, according to a preferred embodiment of the invention, the properties of

30 a diffractive light pipe can be improved by dividing its surface to form pixels, in which its gridded properties are locally uniform. Especially at the end at the light source, the orientation of the pixels can be used advantageously to improve the distribution of the light and thus the brightness of the backlighting of the display.

An example of preferred embodiments of the invention is a binary, gridded like diffraction structure of the surface.

- 5 The patterns on the light pipe surface can be, for instance, of two types of diffractive pixels, which are both of the binary type. Some of the pixels in the vicinity of the light source are oriented so that the diffraction profiles, and thus the pixels themselves are at 90° rotational geometry to each other, when the imaginary axis of rotation is parallel with the normal of the surface of the light pipe. In addition, modified basic profiles or combinations thereof can be used.

Other preferred embodiments of the invention are presented in the subclaims.

10 BRIEF DESCRIPTION OF DRAWINGS

The invention will be described in detail with reference to the following drawings, in which

- Figure 1 shows a known arrangement based on random roughening in order to provide lighting,
- 15 Figure 2 shows a known arrangement, which is based on the use of lens-like scatterers instead of random roughening for directing the light to the object,
- Figure 3 shows a light pipe arrangement according to a preferred embodiment of the invention,
- Figure 4 shows a detail of a light pipe according to a preferred embodiment of the invention,
- 20 Figure 5 shows the diffraction and reflection taking place in a light pipe according to a preferred embodiment of the invention,
- Figure 6 represents the local outcoupling efficiency η of the diffractive structure as a function of the distance measured from the light source,
- 25 Figure 7 shows light pipes according to a preferred embodiment of the invention,
- Figure 8 illustrates the basic profiles of the grooves and ridges of the diffractive structure of a light pipe according to a preferred embodiment of the invention,
- Figure 9 illustrates the pixelized, diffractive basic structure of a light pipe according to a preferred embodiment of the invention,

Figure 10 represents a modified profile and/or pixel structure of a light pipe according to a preferred embodiment of the invention.

Figures 1 and 2 represent methods formerly known from prior art for backlighting.

Figures 1A, 2, 3A, 5A, 7A, 7B, 7C, 9A, 9B, 10A represent the principles of the patterns of the microstructure of the diffraction profile geometry, and are thus not necessarily in the right scale in relation to the macroscopic dimensions or thickness of the light pipe.

DETAILED DESCRIPTION OF THE INVENTION

Figure 3A shows how the illumination of a flat-panel display 301 can be arranged by means of a light pipe 303 according to a preferred embodiment of the invention. The light pipe 303 has a binarized diffraction surface, in which the geometrical properties of the surface profile change when the distance from the light source increases. Locally, the geometrical changes are small as compared to the adjacent formations, and they approximate at a certain accuracy a grid structure, in which the grid constant changes as a function of location. The light 302 is equally strong throughout the whole diffractive light pipe element 303, although individual rays of light 302 are stronger at the first end 303A of the light pipe 303 close to the light source L3 than at the opposite end 303B. The local outcoupling efficiency η of the diffraction element 303C has been changed by utilizing its dependence on the fill factor c . In addition, it is advantageous for the invention to use, for instance, a Lambertian white reflector 304 below the light pipe 303 to reflect or scatter the part of the light which has passed through the bottom of the light pipe 303 in the wrong direction back to the light pipe 303 to be used for the illumination of the display 301.

Figure 3B represents the local outcoupling efficiency η of the diffractive construction according to a preferred embodiment of the invention as the function of a location measured from the light source L3.

Figure 3C represents the local brightness B of the display achieved by a diffractive structure according to a preferred embodiment of the invention as the function of a location measured from the light source L3, when the outcoupling efficiency of figure 3B has been compensated for achieving a constant brightness by changing the geometry of the diffractive profile, e.g. the fill factor. Brightness is constant, and thus independent of location.

The length 30 mm of the horizontal axis in figures 3B and 3C is only an example, and the length and/or width of a real display as well as other dimensions of the light pipe can differ from this substantially.

- Figure 3D illustrates the passage in the light pipe 313 of the rays 315, 16A and 16B of light, which have left the light source L3, and their conversion into rays 15A to 15E, which are transmitted out from the light pipe. Note that in the transmissions and reflections taking place at points 15A to 15E, the macroscopic brightness of the light equals that in Figure 3C outside the light pipe as seen by an observer in the direction of the display, although with regard to an individual ray of light, in a microscopic scale, the intensity of the ray of light is reduced as the function of a distance measured from the light source, also in consequence of multiple reflections and/or transmissions. Uniform brightness is achieved by directing a larger part of the locally available light out from the light source by means of a diffractive structure according to a preferred embodiment of the invention (figure 3A).
- Figure 4 illustrates the structure of the surface geometry of a diffractive light pipe in one of the preferred embodiments of the invention. Characteristic parameters of a binary diffraction profile are cycle length d , fill factor c and ridge height h of the profile. n_1 is the refractive index of the light pipe material, and n_2 is the refractive index of the medium between the light pipe and the display.
- Figure 5A illustrates the propagation of light with the principle of total reflection in a diffractive light pipe according to the invention, in view of a ray of light, which passes in the direction α in relation to the normal of the inner surface of the light pipe. A detail 517, which illustrates the passage of the ray of light at one period of the diffractive structure, is delimited by a dashed line from the light pipe.
- Figure 5B is an enlargement of the detail 517 in figure 5A. The optical geometry is the same as in figure 5A. When a ray of light hits the diffractive profile d , its diffraction is represented by angles of transmission and reflection, β_{pT} and β_{pR} , respectively, certain orders of which are marked in Figure 5B. For instance, 0_R is the ordinary reflection of the principal ray.
- Figure 6 shows the outcoupling efficiency η of the diffractive surface as the function of the fill factor c standardized with the period d , in other words, the dependence of the outcoupling efficiency as the function of the ratio c/d . The dependence is represented for three angles of incidence of the principal ray: 60° (continuous line), 70° (dashed line) and 80° (dotted line). The results shown in the

figure are based on calculated mean values of the transverse electric and magnetic fields of the propagating light. Rays of light, which are directly transmitted or advantageously reflected have been taken into account. The absorption of the white reflector plate on the bottom of the light pipe has not been taken into account in the calculation.

Figure 7 shows, by way of example, preferable embodiments of the invention achieved by using a binary profile of the light pipe (Figure 8). Figure 7A illustrates the principle of a diffractive structure 718 grooved transversely to the propagation direction of the light as seen from above, the direction of the display. Figures 7B and 7C show the principles of light pipe sections 719, 720 made by curved grooving. A dotted line A-B shows the places of the grooves C and ridges of the diffraction profile and the geometric principle as a viewer would see them when looking from the side of the diffraction element 718, 719, 720 (bottom or top edge in the figure) on the level of the surface of the light pipe, perpendicular to the propagation direction of the light. Other diffraction profiles (Figures 8 and 10) are also possible in a light pipe section 718, 719, 720 either as such or by combination. Possible differences in brightness on the display can be equalized by using a wavelike groove structure (Figure 7C).

Figure 8 illustrates alternative diffraction profiles for the surface formation of a light pipe (and pixels contained in it) according to a preferred embodiment of the invention, and related parameters, which influence the optical properties of the surface. Figure 8A shows a binary groove/ridge profile for a diffraction surface and/or its pixels. In the figure, h is the height of the ridges, c is the fill factor and d is the length of the groove/ridge period of the profile. Figure 8B shows a sinusoidal profile, in which h is the height of the ridge, d is the length of the period and c is the fill factor as defined on the basis of the half-wave width of the sinusoidal ridge. As an example of a multilevel diffraction profile structure, figure 8C shows a three-level structure with its characteristic parameters: h_1 and h_2 are the heights of the levels of the grooves of a locally gridded structure, d is the length of the period and c is the fill factor. Figure 8D shows a detail of a diffractive profile structure provided with triangular ridges, in which the height of the ridge is h , the length of the period d and the fill factor c as defined on the basis of the half-wave width of the ridge as in Figure 8B. The fill factor can also be varied by changing the apex angle of the triangular ridge. In addition to these, other profiles can also be used. For instance, profiles that are achieved by combining at least two basic profiles shown by figure 8 can be used either as such, by combining and/or modifying them and/or

combining with them mathematically represented periodical forms, which can be described by means of parameters associated with the basic profiles. An example of this is a diffraction profile, which is obtained from a sinusoidal wave profile (Fig. 8B) by combining with it other sinusoidal profiles, the period lengths and fill factors of which are functions of the mathematical value of the period length and fill factor or phase of the form of a basic profile (e.g. figures 8A to 8D).

Figure 9 shows a preferable embodiment of the invention, in which the diffraction surface of the light pipe consists of pixel-like patterns. The purpose of the pixelization and/or orientation of the pixels is to influence the uniformity of the light at the first end of the light pipe by means of diffraction, and thus to improve the properties of the diffraction surface of the light pipe. The diffractive surface can be divided into pixels so that the pixels closest to the light source form (orientation B) an equalizing portion 902, in which the light of the light source is distributed as a result of diffraction to form a macroscopically uniform lighting. The pixels of such an equalizing portion 902 based on diffraction are preferably positioned according to the orientation B and even in different geometry in relation to the period length and the fill factor or in relation to another degree of freedom, which is essential with regard to the application. The purpose of pixels 903, 904, which are further away in the direction of propagation of the light are either to couple light out from the pipe section in order to produce lighting (pixel 903, orientation A) and/or to distribute the light coming from the light source to make it still more uniform (pixel 904, orientation B). It is advantageous to use more light distributing pixels 902, 904 in the vicinity of the light source 901 than further from it. In this diffraction structure according to a preferred embodiment of the invention used here as an example, the purposes of the pixels are determined on the basis of their orientation (Figure 9A).

Figure 9B shows the propagation of light in a pixel, which equalizes the lighting. As a result of diffraction, the incoming ray of light is distributed in many directions, which are described by means of orders representing intensity maximums. The directions of the diffraction maximums corresponding to the orders ± 2 , ± 1 and 0, which also correspond to the propagation directions of the rays of light, are marked in the figure.

The pixels can be locally homogeneous, and/or the fill factor and period can change within them as the function of a quantity measured from the light source, such as distance. Although the pixelizing is represented here in a rectangular application, it can also be applied in other geometrical shapes, such as the groove patterns shown

in Figure 7, when an uniform backlighting of a display is optimized by the placement of the light source.

Figure 10 shows modifications of the basic profiles of a diffractive light pipe according to a preferred embodiment of the invention. Figure 10A represents a profile, which is binary, but can also be derived from the basic forms of figure 8, as applied to the pixelization of a diffraction surface according to Figure 9, for example. Some of the pixels in figure 10A are deflected from the level of the surface of the light pipe (horizontal) to the angle Φ , some to the angle ϕ , and some are parallel with the surface of the light pipe. After the presentation of the Figures 10A and 10B, it will naturally be clear to a person skilled in the art that in a pixelization, which is incorporated in the structure of a macroscopic piece, the angles of deflection and the relation of the number of deflected pixels to the number of non-deflected pixels in a light pipe also has an effect on its diffraction properties. Figure 10B shows a diffraction profile according to a preferred embodiment of the invention as derived from the basic forms of Figure 8, when the surface formations are deflected to the angle Θ from the level determined by a pixel shown in Figure 10A. It will also be clear to a person skilled in the art that structures, which are skewed in relation to the peak of the surface formation, are also possible in a diffraction profile. Figure 10 represents the principles of the geometry of diffraction profiles, and thus the size and/or angles of deflection of the pixels are not necessarily in the right scale to the periods and/or heights of the surface formations.

The theory related to the prior art about the behavior of light in diffraction, about the effect of the parameters of microgeometry, the properties of the light source and its distance has been dealt with, e.g. in the book *Micro-optics: Elements, systems and applications*, edited by Hans Peter Herzig, Taylor and Francis, 1997, and especially in chapter 2: *Diffraction Theory of Microrelief Gratings* by Jari Turunen.

There are also other publications related to the prior art, such as *Illumination light pipe using micro-optics as diffuser*, *Proceedings Europto series, Holographic and Diffractive Techniques*, SPIE 2951, 146-155. 1996.

A diffraction phenomenon is observed in monochromatic light when the light meets a piece or a group of pieces (grating), the characteristic dimension of which is in the range of the wavelength of light. The incoming ray of light is divided, and its direction of propagation is changed. The new directions of the rays of light, both for the reflected and the transmitted rays, can be expressed by means of the wavelength, its integer orders and the characteristic dimension of the piece participating in the

diffraction. Formulas (1) and (2) can be applied in the calculation of direction angles corresponding to the orders of the propagation directions of the diffracted light. For transmitted orders we have:

$$\sin \beta_{pT} = \frac{p\lambda}{n_2 d} + \frac{n_1}{n_2} \sin \alpha \quad (1)$$

5 and for the reflected:

$$\sin \beta_{pR} = \frac{p\lambda}{n_2 d} + \sin \alpha \quad (2)$$

where α is the angle of direction of the incoming ray of light in relation to the normal of the surface, β_{pT} is the angle of direction of the order p of the conducted light, and β_{pR} is the angle of direction of the order p of the reflected light, p is the order of the ray of light, λ is the wavelength of the primary, incoming light, n_1 is the optical refractive index of the diffractive light pipe, n_2 is the refractive index of the medium surrounding the light pipe, and b is the period of the diffractive structure.

An embodiment of the invention is described here as an example. A prototype is made of the light pipe, with the purpose of illuminating a flat-panel display. Three sources of light are used, the wavelength of the transmitted light being 570 nm. The optimal diffractive structure of the light pipe is implemented with the parameters of the table below.

Quantity	Value
Period length	2.5396 μm
Groove depth	0.5311 μm
Fill ratio c/d	0.2-0.5

The period length of the diffractive profile is preferably designed between 1.5 μm - 3.5 μm . A suitable depth of the grooves in a diffractive structure according to a preferred embodiment of the invention is from 0.3 to 0.7 μm , i.e. in the range of the wavelength, when visible light is used. On the basis of this, it will be clear to a person skilled in the art that by using suitable materials, a technique according to the preferred embodiments of the invention can also be scaled to other electromagnetic wave movements, the wavelength of which differs from that of visible light, such as applications and problems related to medical and/or technical X-raying and/or analysis methods.

By means of the preferred embodiments of the invention, the outcoupling efficiency of the diffraction surface of the light pipe can be increased as a function of the distance measured from the light source to compensate for the reduction of the amount of light used for illumination when moving away from the light source.

- 5 When the outcoupling efficiency is increased at the same rate as the amount of light available decreases, an uniform brightness of the display is achieved.

- 10 The local outcoupling efficiency of the surface of a light pipe according to a preferred embodiment of the invention can be regulated by changing the period of the diffraction profile and/or the depth of the grooves. The order of the mode of scattering and the scattering angle of the outcoupling rays of light can also be regulated by changing the period of the diffraction profile. The dependence of the illumination on the angle of incidence of the ray of light is stronger at the source end of the light pipe than at the opposite end. The distribution of the illumination observed on the surface of the light pipe can be equalized by changing the period of the profile of the diffraction structure.

- 15 In addition, the diffraction profiles and/or even whole pixels can be modified suitably by turning them in relation to three possible degrees of freedom, and/or by tilting the diffraction profile or its elements, elongated surface formations and/or their local formations. Within an individual pixel, the different parts of the diffraction profile can be turned in relation to straight lines parallel with the surface to an angle suitable for the application (Fig. 10B). Even whole pixels can be deflected in angles which differ from the level of the surface of the display (Fig. 10A). The diffraction structure and/or grouping of the light pipe and/or the pixels, grooves and/or ridges contained thereby can also be designed according to fractal geometry.

- 20 A surface according to a preferred embodiment of the invention in a diffractive light pipe can be manufactured directly on the surface by using nanolithographic methods with an electron beam, for instance, or by molding the light pipe. A preferable material for manufacturing the light pipe is polymethyl-methacrylate PMMA. An advantage of the invention is that a light pipe according to it can be manufactured by mass production means and methods based on extrusion, for instance. A further advantage of the invention is that its elaboration for the application can be carried out quickly by constructing a diffractive structure on a selected substrate, whereby the diffractive structure is also indiscernible for the user.

It is also possible to use more complicated profiles than those described in a preferred embodiment of the invention (figures 8 to 10) for uniform distribution of light, but when the structure becomes more complicated, the manufacturing costs are also likely to increase. Complicated techniques are described at least in the
 5 publications by Noponen et al (1992): 'Synthetic diffractive optics in the resonance domain', J. Opt. Soc. Am. A9 1206-1213. and Vasara et al (1992): Applied Optics 31, 3320-3336.

The diffractive structure on the surface of the light pipe can be made either on one side of the light pipe section or on both sides thereof. Diffraction surfaces made on
 10 both sides need not be identical. The invention is especially suitable for use in connection with a light emitting diode (LED), for example. The invention is also very suitable for use with a technique based on liquid crystal displays (LCD), for instance.

It is advantageous if all energy from the light source can be converted into the
 15 lighting of the background of the display. That requirement is met most advantageously with regard to the application of preferred embodiments of the invention when a LED is used as the light source, but also other light sources such as lasers and/or white light sources can be used. It is known for a person skilled in the art that the light can be filtered and/or polarized. It is also known for a person
 20 skilled in the art that use of combined techniques of white light as filtered and/or polarized can be used, including combinations thereof, in which structures that store light energy are used, in other words, solutions based on phosphorescence and/or fluorescence. In order to minimize the amount of light outcoupled from the sides and ends of the light pipe section, the edges of the light pipe section can also be
 25 coated with clear and/or diffuse films or treated with a grinding suitable for the purpose.

In order to make the propagation time of the ray of light in the light pipe section as long as possible, (that is, to maximize the amount of light that is outcoupled for effective use), the light pipe section can be shaped as an asymmetric trapezium or
 30 the like, whereby the energy of the rays of light propagating in the direction of the diffractive surface and being thus otherwise led out from the ends can be utilized for lighting.

Uniform distribution of light at the first end of the light pipe can be influenced by pixelization of the diffraction structure (figure 9). A special portion 902 can be

made at the source end of the light pipe, with the purpose of equalizing the distribution of the light from the light source (figure 9A).

The distribution of light based on diffraction in an appropriate pixel 902 (figure 9) will be demonstrated in the following example. When diffraction of light is discussed in this connection, the directions of the intensity maximums mean the propagation directions of the diffracted rays of light, in which light can be seen as a result of diffraction. When the period length of a grating in the diffraction structure is $2.5\text{ }\mu\text{m}$, the depth of the grooves $0.5\text{ }\mu\text{m}$, the fill factor 0.5 and the wavelength of incoming light is 470 nm with an angle of incidence $\alpha=60^\circ$, intensity maximums are seen in directions that differ from the direction of the 0th order of the transmitted principal ray, which are 8.2° , 16.1° , 23.5° for the corresponding orders ± 1 , ± 2 and ± 3 , respectively. The deviations from the principal ray of the same orders with the wavelength 570 nm are $\pm 10^\circ$, ± 19.3 and ± 27.8 , respectively. When the angle of incidence of the principal ray increases, the diffraction angles corresponding to the intensity maximums decrease to some extent. For example, when the wavelength is 470 nm but the angle of incidence is 80° , a ray of light of the 1st order is seen in the direction 7.3° . In addition, the distribution of the light energy between rays of light representing different diffraction orders depends strongly on the angle of incidence of the principal ray.

Claims

1. A light pipe for providing backlighting of a flat-panel display by means of at least one light source, wherein

- the light pipe is limited by a certain first surface

5 - said surface comprises patterns

- said patterns have diffractive properties for coupling the light out from the light pipe

- said patterns comprise uniform, mutually different areas with a certain distribution on said first surface.

10

2. A light pipe according to Claim 1 wherein

- said patterns comprise parallel, straight or bowed, elongated surface formations, the height and width of which differ from the environment,

15 - said patterns comprise a certain first uniform area, in which a certain characteristic parameter has a certain first value;

- said patterns comprise a certain second uniform area, in which said characteristic parameter has a certain second value, which differs from said first value;

20 and the surface formations in said first area differ from the surface formations in said second area with regard to said characteristic parameter, and said characteristic parameter is at least one of the following: the orientation of the pattern, the distance between the pattern and the light source, the

- period length,

- fill factor,

- fill ratio,

25

- height,

- characteristic degree of modification

- angle of deflection

between the elongated surface formations of the pattern, which differ from the environment.

- 5 3. A light pipe according to Claim 2, wherein the value of at least one characteristic parameter depends on the quantity, which has been defined in relation to the light source, such as the distance from the light source.
- 10 4. A light pipe according to Claim 2, wherein the elongated patterns of the surface formations change gradually from the first shapes of the first end of the pattern at the light source side to the other shapes of the opposite side of said pattern at the other end in a manner depending on a quantity, which is dependent on the light source, such as distance.
- 15 5. A light pipe according to Claim 2, wherein the local plane in the area of the pattern, which plane is determined by the peaks of the surface formations of the patterns is in relation to a level determined by the first surface of the light pipe at an angle, which depends on a quantity, which is dependent on the light source, such as distance.
- 20 6. A light source according to Claim 2, wherein the fill ratio increases when moving from the end at the side of the light source to the opposite end of the light pipe.
- 25 7. A light source according to Claim 1, wherein the distribution of the patterns depends on a quantity, which is dependent on the light source, such as distance.
8. A light pipe according to Claim 1, wherein its first surface is on the side of the light pipe, which is closest to the display.

9. A light pipe according to Claim 1, wherein the elongated shapes of the surface formations in the patterns are repeated as similar in a certain uniform area of the surface of the light pipe.
- 5 10. A light source according to Claim 1, wherein the fill ratio increases along the central line of the light pipe from the end at the side of the light source to the opposite end of the light pipe, and the elongated formations, which differ from the environment, are perpendicular to the central line.
- 10 11. A light source according to Claim 1, wherein the fill ratio is between 0.2 and 0.5.
- 15 12. A light pipe according to Claim 1, wherein the fill ratio increases as measured along a straight line when moving away from the light source, and the elongated surface formations, which differ from the environment, are bowed as defined by conic section geometry, whereby the midpoint defined by the dimensions of the light source is located essentially at a focal point characterizing the bow.
- 20 13. A light pipe according to Claim 2, wherein the period length of its diffractive surface in a diffractive structure is between 1.5 and 3.5 μm .
- 25 14. A light pipe according to Claim 1, wherein the depth and/or height of the elongated surface formations of its diffractive surface in a diffractive structure is between 0.3 and 0.7 μm .
15. A light pipe according to Claim 1, wherein the light pipe has a polygonal shape, with at least one angle, which differs substantially from 90°.

16. A light pipe according to claim 1, wherein the light pipe has fluorescent and/or phosphorescent properties.

17. A light pipe arrangement comprising

5 - a light source

- a display,

-a light pipe and

-a base plate of the light pipe

wherein

10 - the light pipe is limited by a certain first surface

- said surface comprises patterns

- said patterns have diffractive properties for coupling the light out from the light pipe

15 - said patterns comprise uniform, mutually different areas with a certain distribution on said first surface.

18. A light pipe arrangement according to Claim 17, wherein the number of light sources is three.

(57) Abstract

The invention relates to a new light pipe (313) for providing backlighting (312) of a flat-panel display (311) by means of at least one light source so that the light pipe has at least one surface which
5 comprises patterns. The patterns have diffraction properties for conducting the light in the direction of the display, and the patterns comprise uniform, mutually different areas having a certain distribution on the surface of the light pipe. The local outcoupling efficiency of the light pipe depends on the characteristic properties of the patterns, which
10 are dependent on the distance to the light source or its wavelength.

Figure 3A

Figure 3A

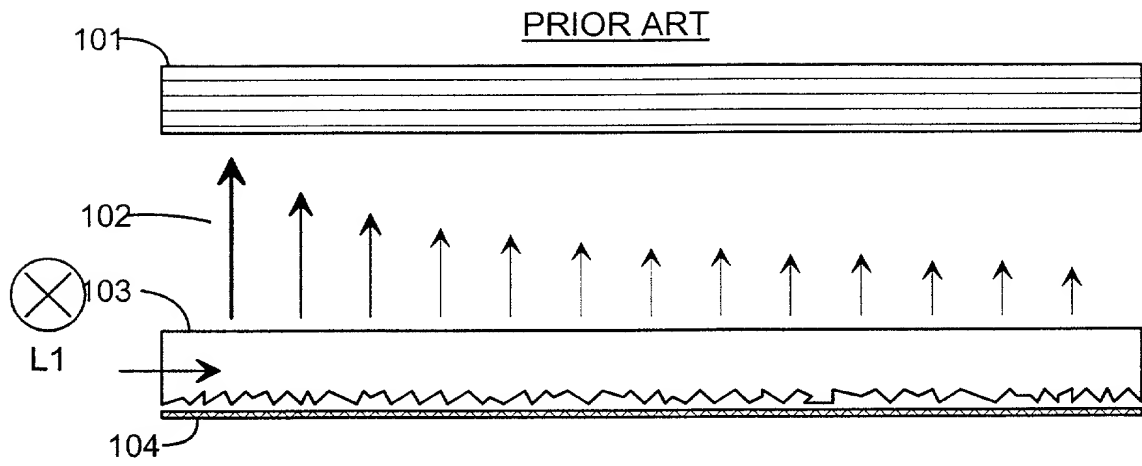


FIGURE 1A

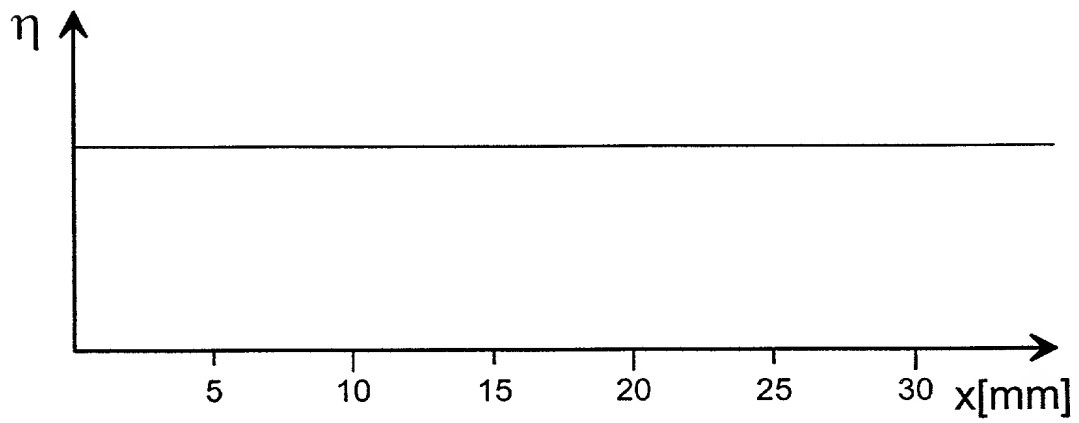


FIGURE 1B

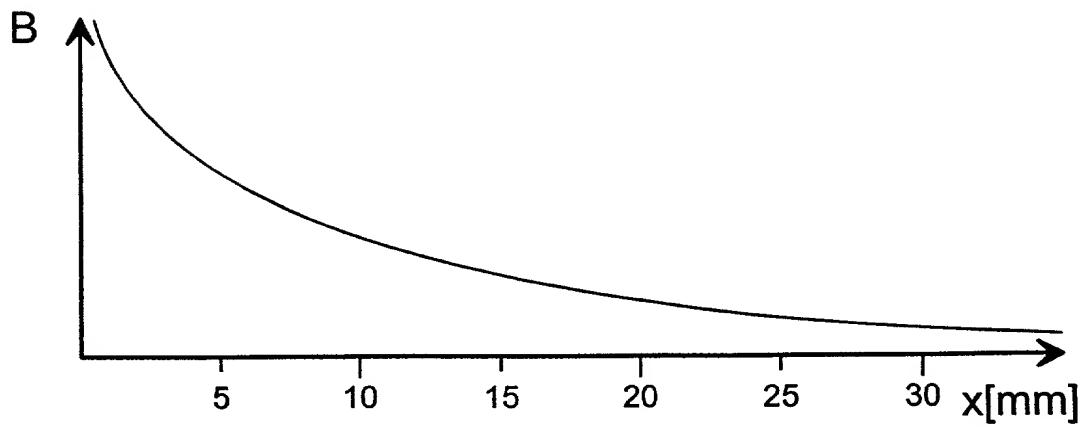


FIGURE 1C

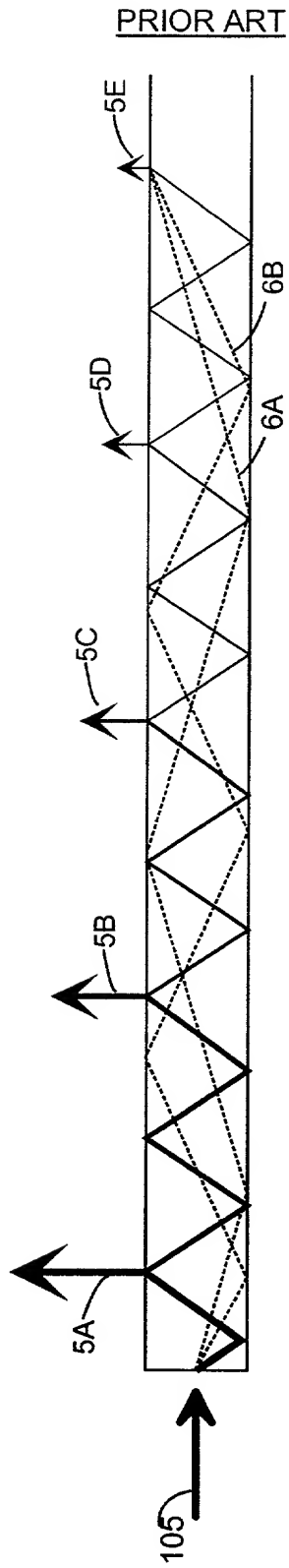


FIGURE 1D

PRIOR ART

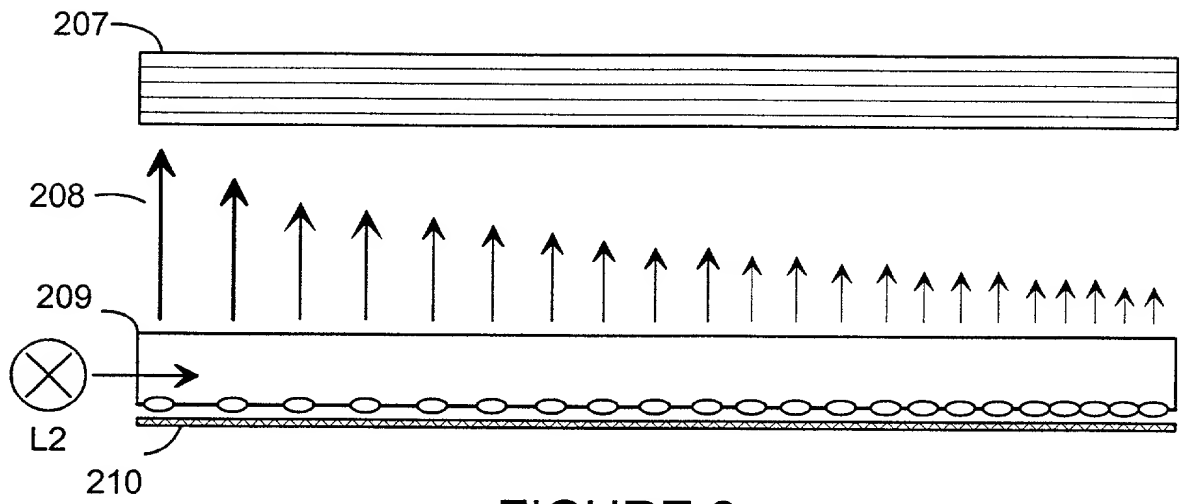


FIGURE 2

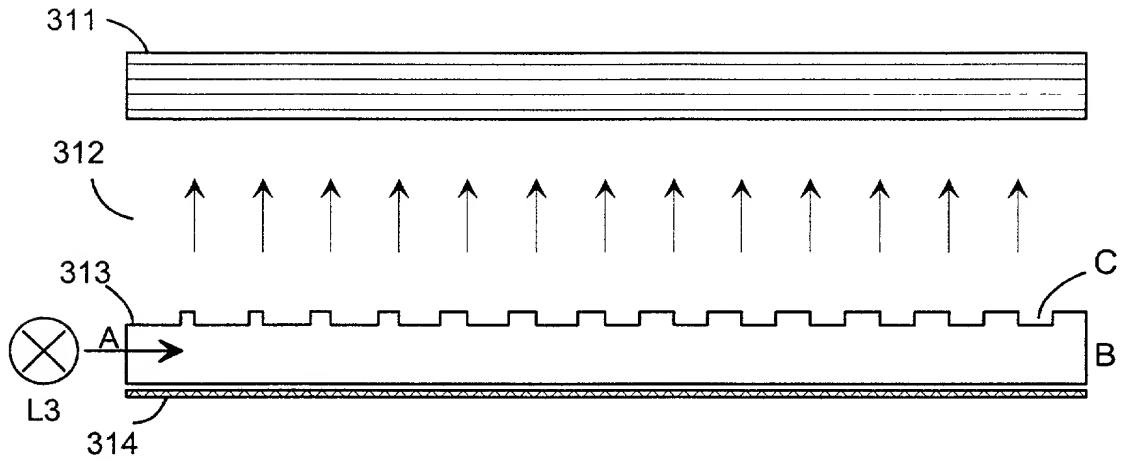


FIGURE 3A

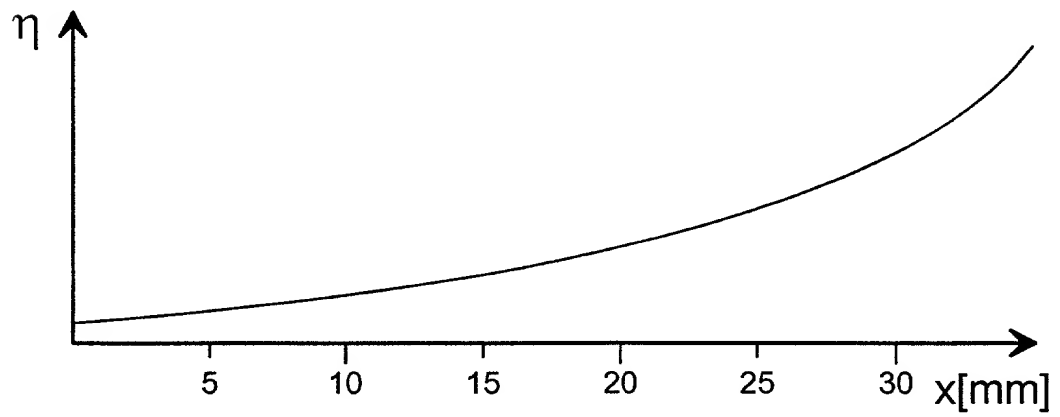


FIGURE 3B

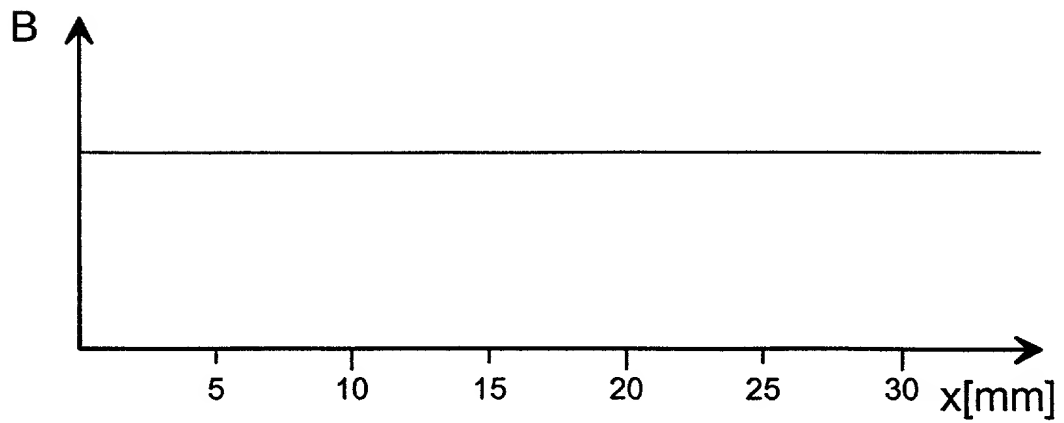


FIGURE 3C

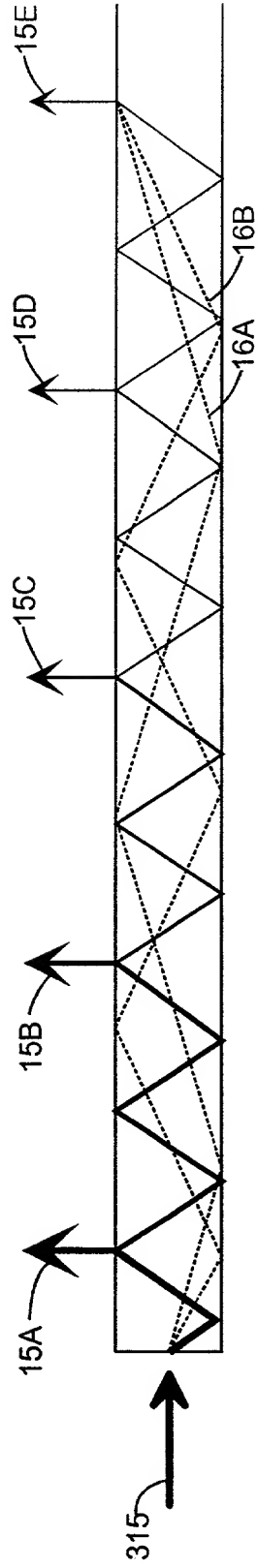


FIGURE 3D

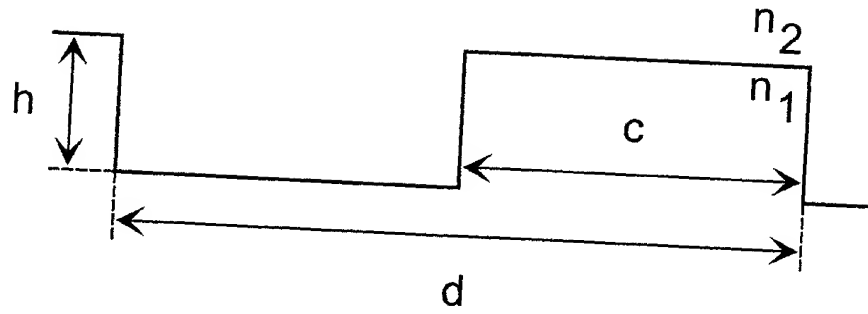


FIGURE 4

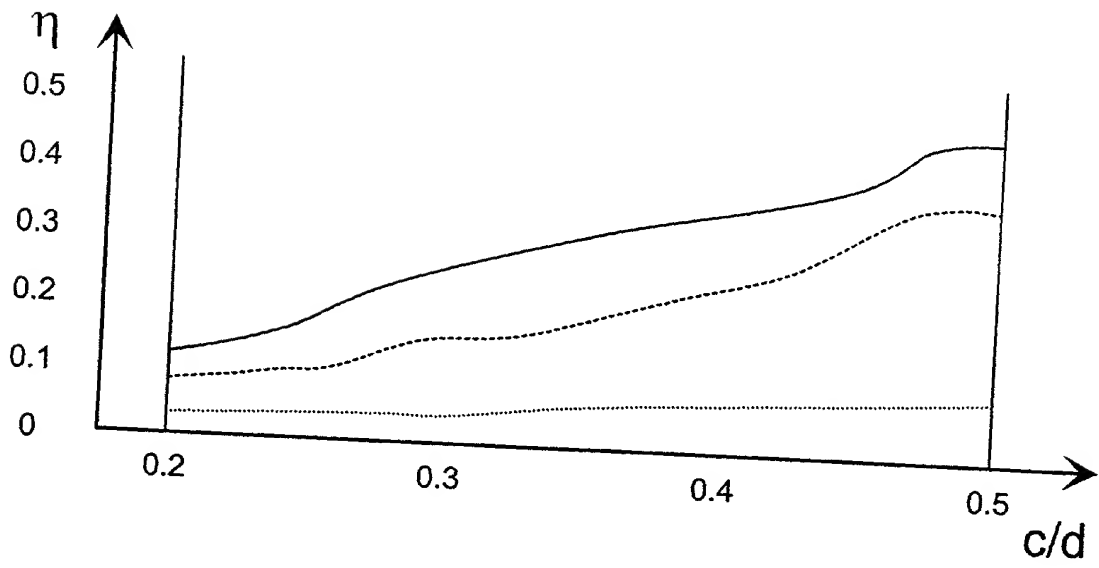


FIGURE 6

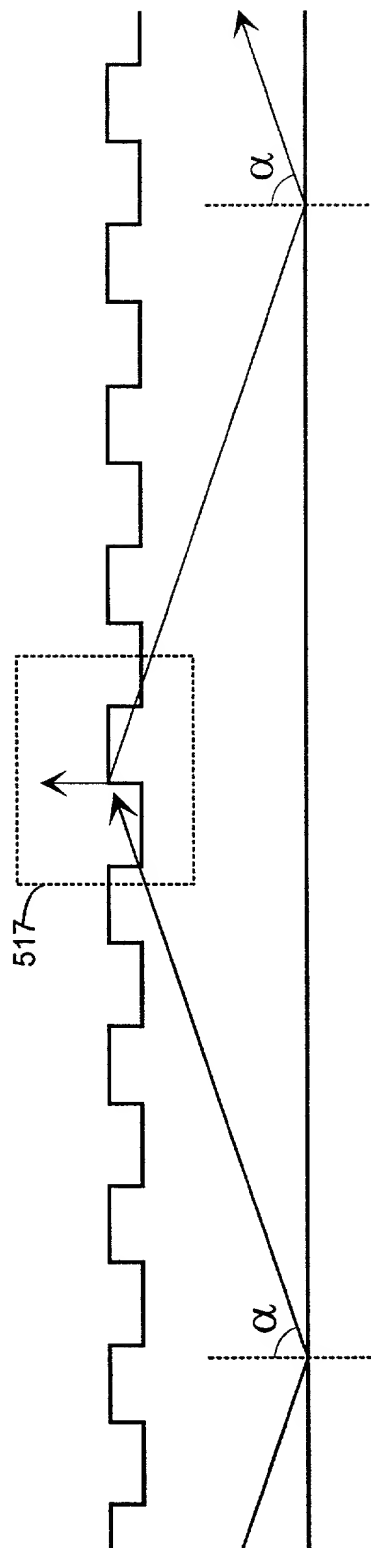


FIGURE 5A

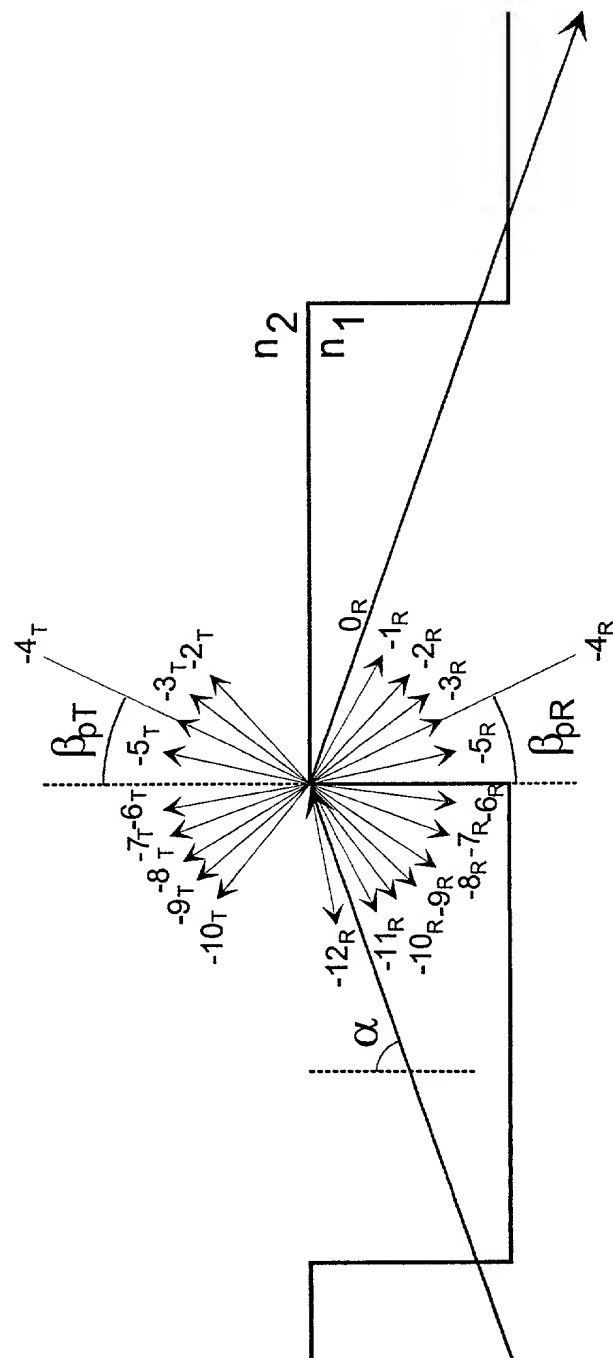


FIGURE 5B

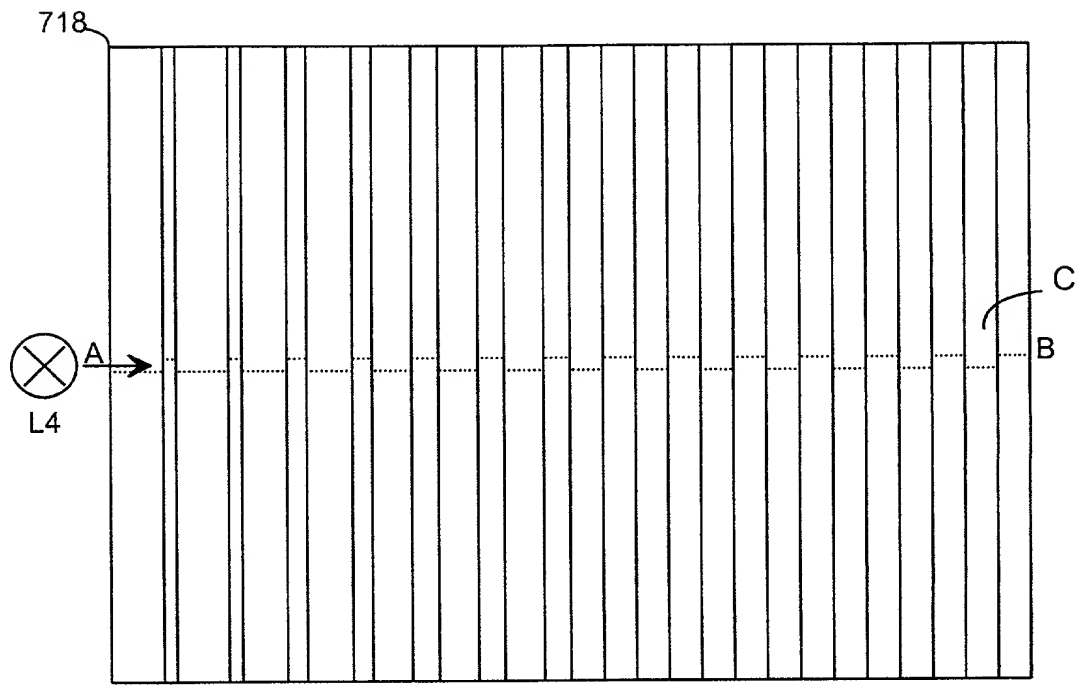


FIGURE 7A

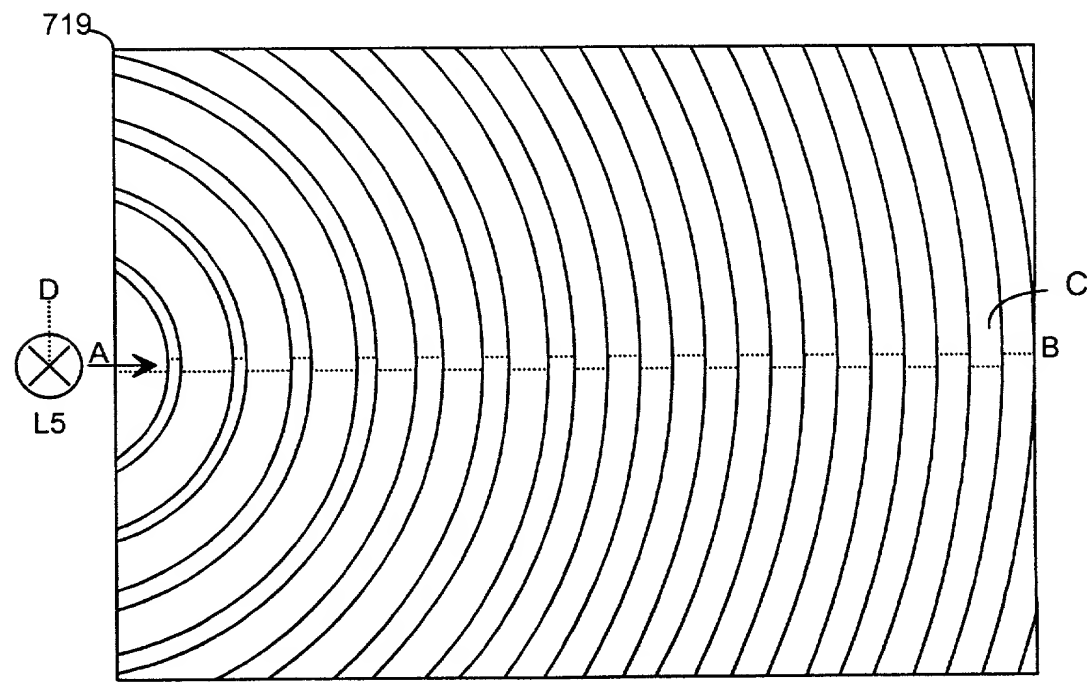


FIGURE 7B

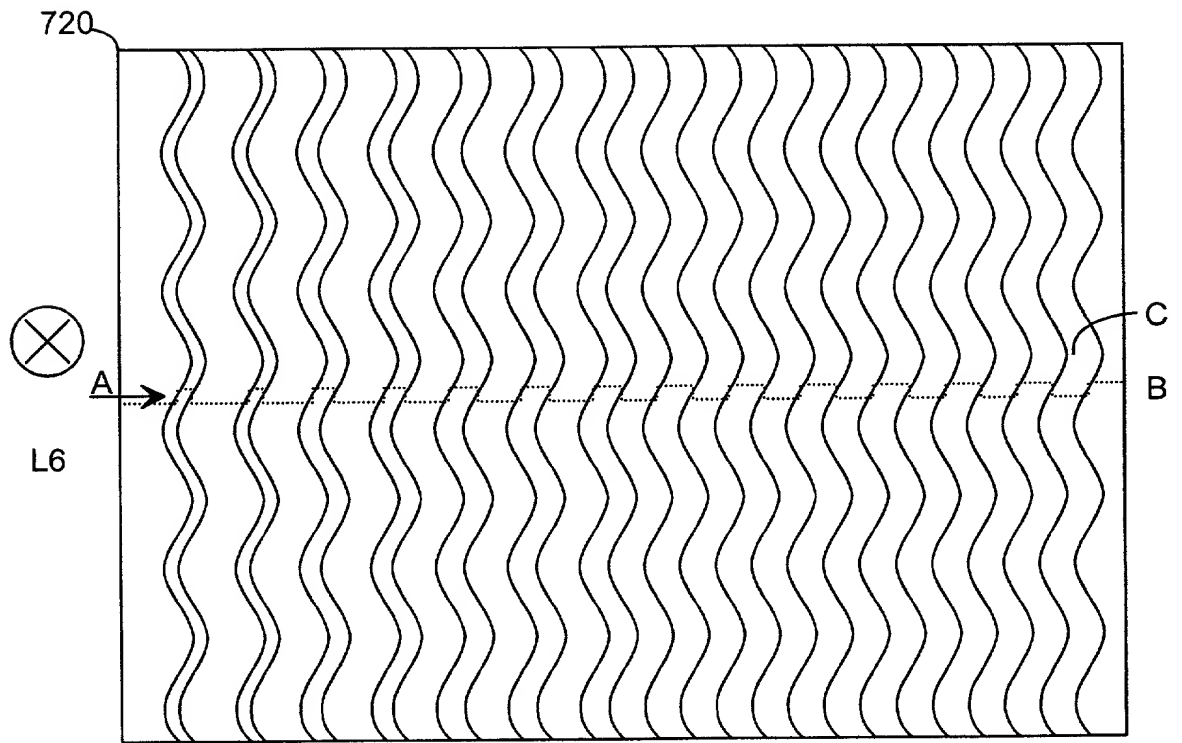


FIGURE 7C

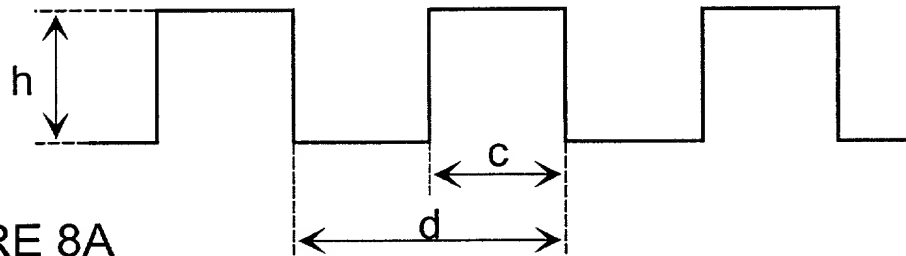


FIGURE 8A

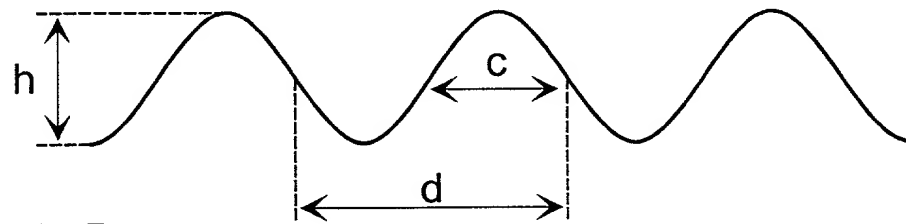


FIGURE 8B

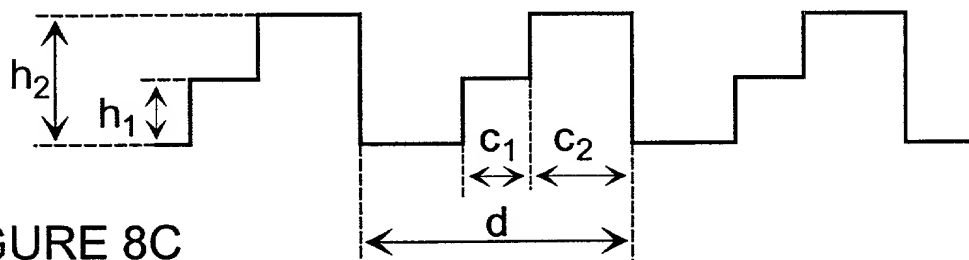


FIGURE 8C

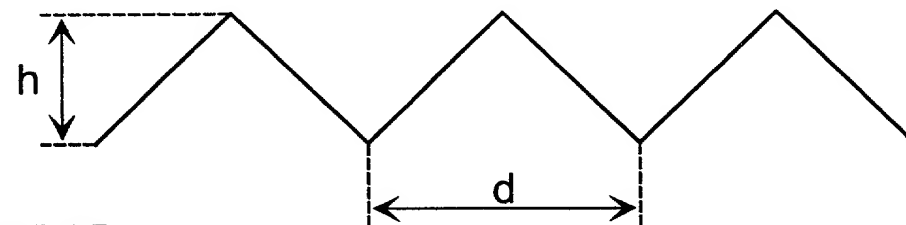


FIGURE 8D

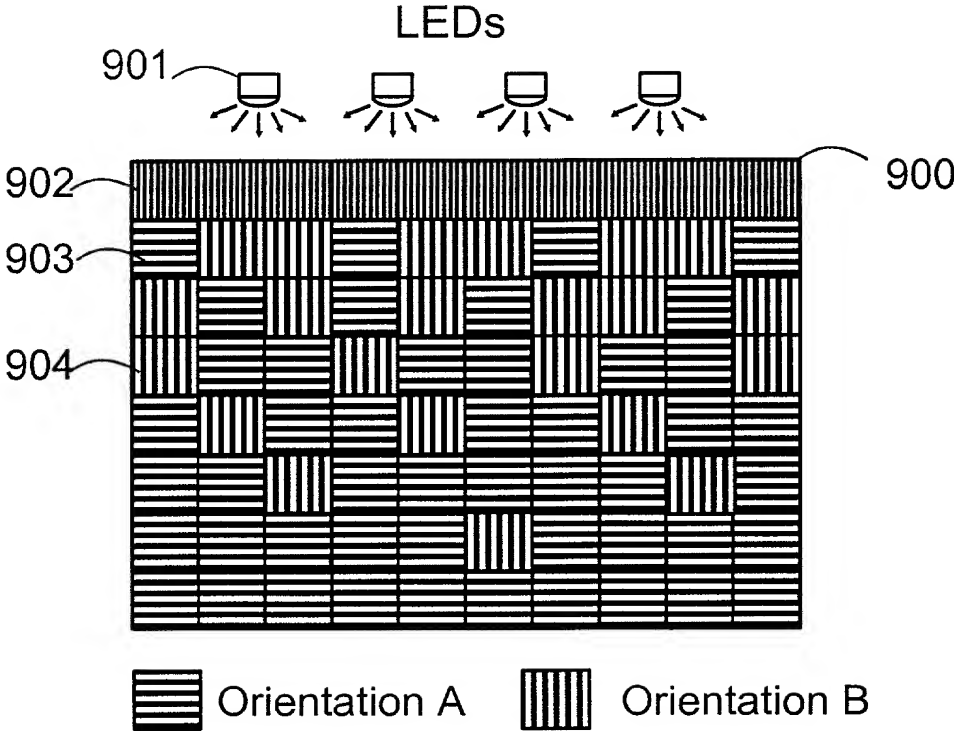


FIGURE 9 A

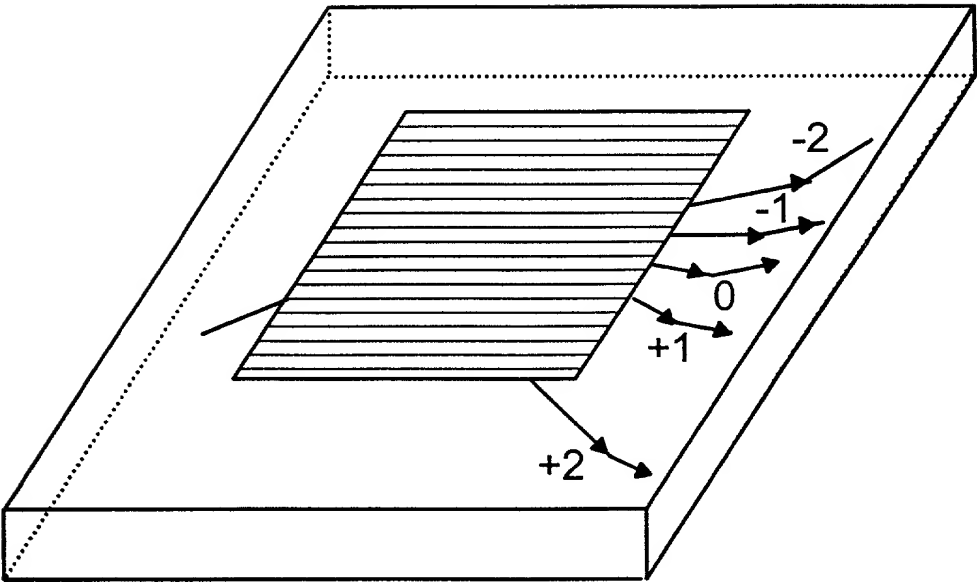


FIGURE 9 B

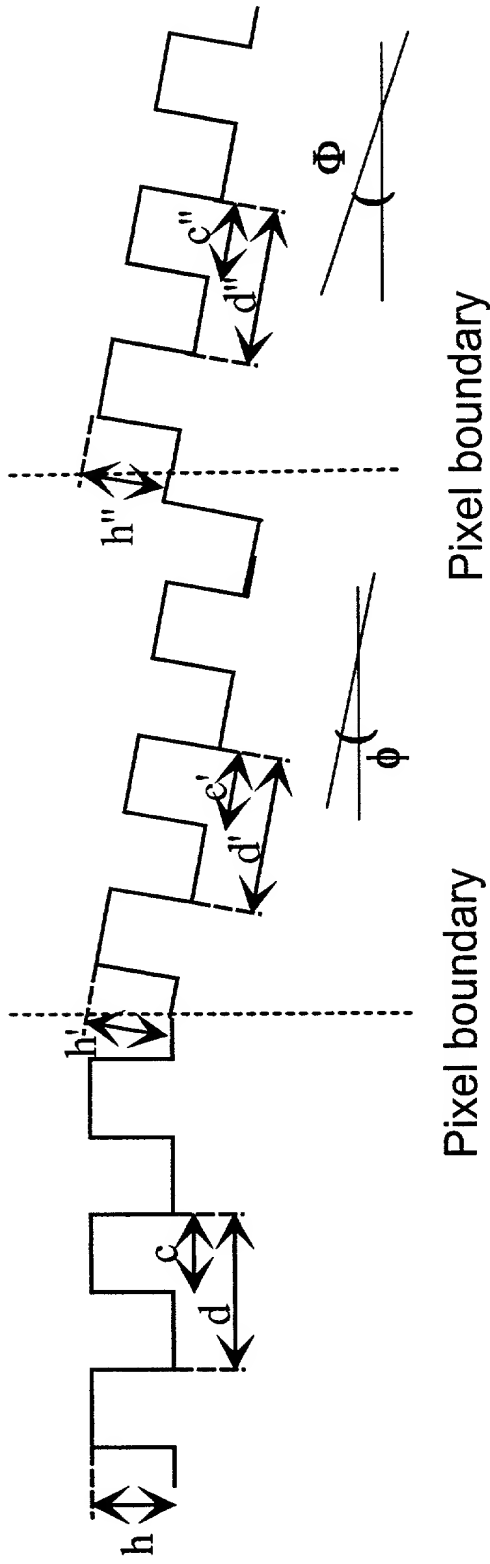


FIGURE 10 A

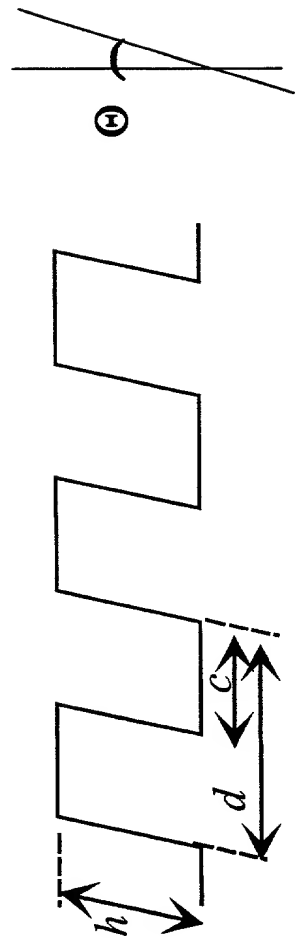


FIGURE 10 B